UNIVERSITY OF CALIFORNIA · COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
BERKELEY, CALIFORNIA

CIRCULAR 359
April, 1944

NEMATODE-RESISTANT ROOTSTOCKS FOR DECIDUOUS FRUIT TREES

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THE GARDEN, or root-knot, nematode (*Heterodera marioni*)[3] has become distributed in various areas throughout California. In many sandy soils this pest now prevents the establishment of peach, nectarine, almond, plum, and prune orchards on the rootstocks that were formerly most successful. Many mature orchards have, through its accidental introduction, been materially reduced in vigor.

Figure 1 shows the knots (actual size) caused by nematodes of this species on the roots of a peach tree. These microscopic eelworms enter the tender tips of new roots in immense numbers and cause swellings and distortions that restrict the free movement of water and plant foods. Heavily infested mature trees decline and may eventually die. Young trees in infested soil are stunted and fail to attain mature size. Many may be killed outright, or first sunburned and later girdled by flat-headed borers. As a rule a whole orchard is not severely affected; rather, it may contain scattered sandy spots where the nemotode population is great enough to cause noticeable damage. There are, however, large sandy areas where orchards cannot be grown except on certain resistant rootstocks.

Since no sure means has been discovered for eradicating this pest or permanently decreasing the number present, the most practical way to grow orchards in infested soils is to use resistant rootstocks. This circular is a summarized report on fifteen years of experimentation designed to adapt deciduous fruit trees to nematode-infested soils. Much of the work has been done with nursery stock near Delhi in Merced County; and many seedlings of peach, nectarine, almond, plum, apricot, cherry, pear, quince, apple, and walnut varieties have been tested.

Encouraging results have been obtained with the seedlings of several peaches and plums; and for some other species the degree of resistance or tolerance has been determined. Certain peach stocks found to be resistant have now been tested in orchards for ten years; and since the industry is beginning to use some of them, the results secured to date with all the species may well

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[3] For general information on the root-knot nematode see: Tyler, Jocelyn. The root-knot nematode. California Agr. Exp. Sta. Cir. 330:1–34. 1933. (Revision in press.)

be presented. Progress reports upon these investigations have already been published.[4]

Several species of nematodes damage the roots of deciduous fruit and nut trees. It has not been determined, however, whether the rootstocks resistant to the knot-forming species may prove resistant to the others also. These other

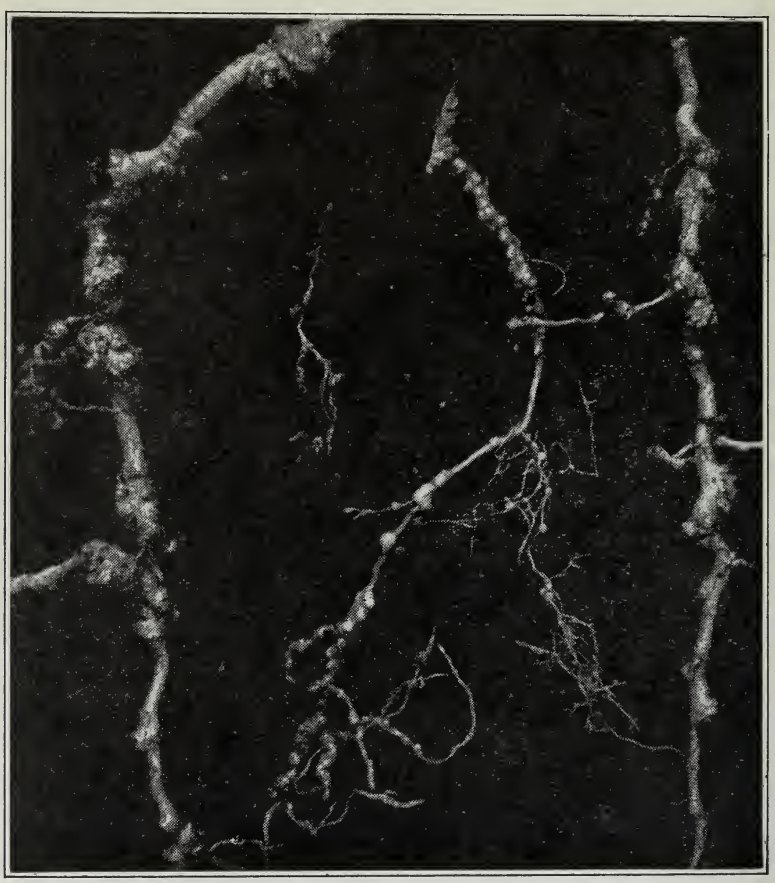

Fig. 1.—"Beads" or galls of root-knot nematode on peach roots. These are natural size. Galls are sometimes much larger, however, than here shown. The "beaded" arrangement distinguishes them from the large knots caused by the crown-gall disease.

species do not cause galls (or knots) on the roots and, being microscopic, are difficult to detect. The meadow nematode appears to be doing some injury to stone fruits, walnuts, and figs in certain areas of the state. Preliminary experiments have been initiated in Riverside and Ventura counties to find rootstocks

[4] Tufts, Warren P. Nematode resistance of certain peach seedlings. American Society for Horticultural Science, Proceedings 26:98–100. 1929.

Tufts, Warren P., and Leonard H. Day. Nematode resistance of certain deciduous fruit tree seedlings. American Society for Horticultural Science, Proceedings 31:75–82. 1934.

Day, Leonard H., and Warren P. Tufts. Further notes on nematode-resistant rootstocks for deciduous fruit trees. American Society for Horticultural Science, Proceedings 37:327–29. 1939.

resistant to it. In Santa Clara County, an entirely new nematode species is apparently damaging walnut trees in one orchard; test trees of ten walnut species have been planted there.

NEMATODE RESISTANCE OF VARIOUS FRUIT-TREE ROOTS

Apricot.—The apricot root has long been known to be practically immune to the root-knot nematode. In California, on infested soils, it has served as a stock for apricot varieties and, to a limited extent, for plums and peaches. Even in the absence of nematodes, however, many plum and prune varieties do not thrive on apricot roots; and peaches in general on apricot roots prove disappointing in both growth and fruitfulness. As a rule, peach is the root preferred for apricots by growers in the sandy soils of many areas.

Nematode resistance appears to be characteristic of all apricot seedlings: in the nurseries at Delhi seedlings of forty-eight apricot varieties stood for two to three years without infestation adjacent to susceptible peaches that were severely attacked. The commonly preferred Blenheim and Royal seedlings were among those tested.

Myrobalan Plums.—Several types of myrobalan, or cherry, plum have been tested in the nursery at Delhi. Of these, some were grown from seeds; others from stem cuttings of myrobalan seedling trees growing in the University orchard at Davis. Under the conditions of these trials many of the seedlings were infested, and some strains grown by cuttings proved resistant. One, Gregory 29, is the most promising and vigorous-growing myrobalan with which the authors have worked. Since it produces almost no fruits, it is propagated exclusively by cuttings. It has been used in California for ten or fifteen years as a rootstock for plums and prunes and to date appears satisfactory. Apricot varieties also appear to be congenial with it. Few trees, however, have been seen growing on it in the sandy nematode-infested soils.

Marianna Plums.—Rooted stem cuttings of the Marianna variety and several vigorous seedling selections of this plum appear immune to nematode attack. The seedling selections grow well from stem cuttings. Marianna is supposedly a natural cross between myrobalan and a Wild Goose plum (*Prunus Munsoniana*) of Texas. Although it was introduced into California over fifty years ago, not till recently were many orchards planted upon it. Mature trees of apricot and some eighteen plum and prune varieties on Marianna have been under observation for many years, mainly in Placer and Sutter counties. The following plum varieties apparently do well on Marianna in those districts: Beauty, Burbank, Duarte, Kelsey, Santa Rosa, Satsuma, Wickson, California Blue, Grand Duke, Pond (Hungarian), President, Yellow Egg, Robe de Sergeant, and possibly French and Imperial prunes. Gaviota, though slow-growing, finally made good trees, whereas Diamond, Clyman, and Giant were somewhat dwarfed.

In Sutter County the French prune tree apparently does not grow so large on Marianna as on myrobalan root. Robe de Sergeant has made more uniform trees on Marianna root than on myrobalan. In a young orchard, Imperial prunes on Marianna began bearing two years earlier than on myrobalan, a fact which might indicate that this prune might decline early on Marianna root, as it does on peach in that area. In Placer County old orchards of Presi-

dent plum on Marianna indicate that this root may be at least a partial solution to the troublesome rootstock problem with this variety.

According to observations of young orchards in the San Joaquin Valley, in sandy nematode-infested soils, plums on Marianna may prove satisfactory. They are not old enough, however, for final success to be predicted. In one orchard, two-year-old Santa Rosa plums on Shalil peach root had to be treated with zinc for little-leaf, whereas those on Marianna were free from that trouble. In soils of the southern San Joaquin Valley a few experimental trees of President plum and Robe de Sergeant prune on rooted cuttings of the vigorous Marianna seedling selections 2623 and 2624 also promise well. Marianna and its seedling selections are less affected by crown gall than are ordinary myrobalan seedlings. Marianna 2624 appears rather promising as a stock in soils infected with the oak root fungus (*Armillaria*). In a test orchard near Vacaville, French prune trees ten years old on Marianna 2624 and 2623 are performing normally. Apricots apparently do as well on these stocks as on the parent Marianna.

Since the Marianna root apparently equals myrobalan seedlings in resistance to excess water in the soil, it can be used for plums, prunes, and apricots in any low, wet area where nematodes are a problem.

Other Plum Species and Varieties.—Nursery tests of resistance to root knot (of one to three years' duration) have been made with seedlings or rooted cuttings of many other plum varieties and species of *Prunus,* with the following results:

Black Damas C (East Malling selection). Rooted cuttings. Free from knots.
Brompton (East Malling selection). Rooted cuttings. Free from knots.
Cheresoto (*P. Besseyi* × *P. americana*) seedlings. Some free from knots.
Etter's Best (perhaps *P. subcordata* × *P. domestica*) seedlings. Some free from knots.
French prune seedlings. Some free from knots.
Grand Duke seedlings. Some free from knots.
Improved Wild Goose Plum (*P. Munsoniana*) seedlings. Free from knots.
Italian prune seedlings. Free from knots.
Methley (*P. cerasifera* × *P. salicina*) plum seedlings. Some free from knots.
Prunus americana seedlings. Three-year test. Free from knots.
Prunus bokhariensis (P.I. 40229) seedlings. Some free from knots.
Prunus bokhariensis (P.I. 40224) seedlings. Some free from knots.
Prunus bokhariensis (P.I. 40223) seedlings. Some free from knots.
Prunus hortulana seedlings. Three-year test. Free from knots.
Prunus Munsoniana. Three-year test. Free from knots.
Prunus spinosa hybrids with *P. domestica* (P.I. 32673) seedlings. Free from knots.
Robe de Sergeant seedlings. Free from knots.
Santa Rosa seedlings. None free from knots.
St. Julien E (East Malling selection). Rooted cuttings. Free from knots.
St. Julien G (East Malling selection). Rooted cuttings. Free from knots.
St. Julien 3P (University of California selection). Rooted cuttings. None free from knots.
Warwick Drooper (East Malling selection). Rooted cuttings. Free from knots.
Wickson seedlings. None free from knots.

With some of these plums the tests were rather inconclusive because of various factors such as proximity to susceptible roots, and locations in the nursery where the concentration of nematodes was small.

Since *Prunus Munsoniana* is supposedly a parent of the immune Marianna plum, it is interesting to note that its seedlings remained free from attack.

Almond.—Seedlings of the common commercial almond varieties are highly susceptible to nematodes. Fortunately almonds can be grown (under favorable conditions) on peach roots; and almond trees up to eight years of age on the resistant peach roots indicate that these are as suitable as the seedlings of Lovell or other peach varieties used in noninfested soil (fig. 2). Resistant

Fig. 2.—Four-year-old Texas almond on Yunnan peach roots. In August of its fourth season's growth, it was 18 feet in height and 6½ inches in trunk diameter. Although growing vigorously, this tree is also producing a satisfactory crop. It replaced a tree killed by nematodes. The stunted trees near by are three years older and are on common almond roots.

almond seedlings would, however, be very acceptable because almonds are, under many conditions, more successful on almond-seedling roots than on peach. Though a few individual almond seedlings have shown considerable resistance, their seeds have not produced a high percentage of seedlings that retain the resistance of the parent.

Occasional "peach-almonds" have appeared among the almond seedlings in the test nurseries. They are perhaps open-pollinated hybrids between peach and almond. As a rule they grow much more vigorously than the parent varieties, and some are moderately resistant to nematode injury. Progeny of

these moderately resistant individuals have not shown much resistance: only a few grow vigorously like the parent, and some are dwarfish.

Cherry.—The cherry rootstocks commonly used for sweet cherries in California have been planted in the nematode-test nursery for four consecutive years. In no trial did either mazzard seedlings or Stockton Morello roots develop root knots. In three of the four years, mahaleb roots were lightly affected. In all these tests, common peach and almond seedlings in adjacent rows suffered severely. There is a similar report from Tennessee that mahaleb roots were attacked, though not seriously injured.

Mahaleb, the deepest-rooted of the three rootstock species, seems particularly adapted to sandy spots. Since no orchards have been found upon it in the nematode-infested soils, no observations have been made of its behavior under such conditions. But since in some affected areas trees of sweet cherry varieties on mazzard and Stockton Morello are short-lived, mahaleb might well be tried there, at least in a small way, especially in comparison with mazzard roots. Stockton Morello is apparently not a promising rootstock for sandy soils.

Pear.—Seedlings of thirteen pear varieties were studied for three years in the test nursery at Delhi. Those from seed of Winter Nelis, P. Barry, Easter, and Hardy showed light infestation only, whereas those from Bartlett, Bosc, Angouleme, Howell, and Comice were moderately but not severely attacked. If the results of these tests are generally applicable it is important that seedlings of Winter Nelis were among the least affected, because they are frequently used by nurserymen and make excellent nursery stock. They grew well in the infested sandy soil at Delhi. The "French" pear rootstocks formerly imported from Europe came from seeds of the same species as the varieties included in this test. In Florida, as a rule, pears on "French" roots have proved successful even in heavily infested soil.

Apple.—The seedlings of two apple varieties—Delicious and Rainier—were planted in the nematode-test nursery. These were completely resistant during the one year when they were grown in heavily infested soil. Delicious seeds are a rather common source of seedling stock among the propagators in Oregon and Washington who supply California nurserymen with seedling "lining-out" stock, and this variety is rated among the best for the purpose. In other states, apple seedlings are reported to be attacked, but not sufficiently injured to prevent the successful growth of orchards in infested soil.

Quince.—The quince is propagated by California nurserymen almost entirely by stem cuttings—a method by which most varieties will propagate rather freely. Rooted cuttings of the commercial varieties Burbank, Rea, and Orange were grown for two years in heavily infested soil at Delhi without developing root knots. The French type, known as Angers, most commonly used for propagating pear varieties upon quince, was also resistant under test conditions. In the southern states, quince is reported to be attacked by nematodes, but seldom injured.

Walnut.—Though only slight infestation of Northern California black and English (Persian) walnut seedlings was noted in the test nursery, apparently the nematodes in heavily infested soils in orchards will sometimes retard young walnut trees, and English roots are more susceptible than Northern California black. By nitrate fertilization and frequent watering, however,

walnuts can be grown under such conditions; and once the trees are well established, the injury appears slight. Where there is no danger of flooding or of high water table, which might cause infections by crown-rot fungi, the Northern California black walnut is the safest root for nematode-infested sandy soil. It is also practically resistant to oak-root-fungus disease.

Peach and Nectarine.—The seedlings of 180 peach and 44 nectarine varieties have been tested for nematode resistance. Most of them proved highly susceptible. Seedlings of several varieties, however, showed considerable resistance, though none were completely immune. In heavily infested soil, all these "resistant" seedlings may show a few knots, and some of each variety may become heavily beaded. They may well be considered as "tolerant" rather than resistant. Seedlings of most of the resistant varieties were planted in orchard form and budded over to commercial peach and almond varieties to determine their practical value—their permanency of resistance and their serviceability as rootstocks. From all standpoints and after ten years of trial, seedlings of Shalil, Bokhara, and Yunnan appear most promising; but perhaps the time has been too short to reveal all their merits and faults. The following is a list of varieties whose seedlings have been tested:

PEACHES

A.I. (P.I. 43124)
Alpha Tuscan
Ames No. 1
Annabel
Australian Saucer
Babcock
Belle
Bell October
Bilyeu
Blood Cling
Blood Cling (Riverside)
Blood Leaf
Blood Peach (P.I. 48508)
Bokhara
Bolivian Cling
Brackett
Bresquilla
Buckhorn
Burton Hales Early
Cameo
Captain Ede
Carman
Carota
Carpenter
Champion
Chilow
Cotogna Di Siena
Crimson Cling
Cuban Nut
Currie Free
Dahling Cling
Decker
"Dwarf peach" (P.I. 41395)
Early Crawford
Early Elberta
Early Imperial
Early Strawberry
Early Wheeler
Elberta
Elberta Cling
Engle
Eureka
Everbearing
Fay Elberta
Fitzgerald
Foster
Frank
Gaume
George IV
Gilla Tardeva di Milano
Gillingham
Globe
Golden Cling
Golden Queen (P.I. 68353)
Golden Sweet Cling
Goodman Choice
Grosse Mignonne
Haight Late Free
Halford No. 1
Halford No. 2
Harris
Harris Yellow Cling
Hauss
Heath Cling
Hiley
Hobson
Honey
Ideal
Illinois
Imperial
Improved Muir
Jewel
J. H. Hale
J. M. Mack
Klondike
Krummel
Lady Palmerston
La Grange
Late Champion (P.I. 43129)
Late Crawford
Late Elberta
Lemon Cling
Lemon Free
Leona
Levy (Levi Cling) (Henrietta)
Libbee Cling
Lippiatt (Lippiatt's Late Red)
Lovell
Lukens Honey
Mammoth Heath
Mary
McDevitt Cling
McKevitt Cling
Miller Late
Ming Tomb
Mississippi
Monte Vista Cling
Morellone
Mother
Motion Cling
Mountain Rose
Mowrey Strawberry Cling
Muir
Muir Perfection
Newhall
Niagara
October Indian

PEACHES (*Continued*)
Old Mixon Free
Opulent
Orange Cling
Osprey Improved
Pallas
Paloro
Paragon (P.I. 43135)
Pattison
Peak
Peregrine
Perfection
Phillips Cling
P.I. nos.:
24807
32374
35201
43289
43290
43291
43296
43568
55563
55813
55835
55836
61302 (Quetta×Bolivian Cling)
Picquet Late
Pinkham
Pomona
Pratt-Low
Raisin Cling
Sabichi Winter
St. John
Salwey
Sea Eagle
Selma
Shalil group:
P.I. 63850 (= Shalil)
P.I. 63851
P.I. 63852
Shamrock
Sherman Cling
Shipper Cling
Sims Cling
Smith
Smith Indian
Stark Summer Heath
Stearns
Strawberry Cling
Strawberry Free (Vina)
Stump
Susquehanna
Sutter Creek
Texan
Thurber
Transvaal Yellow
Triana
Tribble Pride
Triumph
Tuskena (Tuscan)
Up to Date
Vaal Mammoth (P.I. 100,633)
Van Emmon
Waldo
Ward Late (Morris White?)
Washington
West Late Free
Wilbur
Wilma
Winter Freestone
Yunnan group:
P.I. 55885
P.I. 55886
P.I. 55888

NECTARINES

Advance
Ansenne
Davis
Diamond Jubilee
Dixie
Downton
Early Newington
Fisher Yellow
Gaylord
Gold Mine
Gower
Griffith
Hardwicke
Humboldt
J. C. Wees
Kathryn
Lippiatt Late Orange
Lord Napier
Mexican
Milton
Muir Seedling
New Boy
Newton
New White
Ozark
P.I. nos.:
29227
30648
65976
65977
Pineapple
Quetta
Red Cling
Red Roman
Robinson
Smith
Spanish
Spencer
Traveller
Stanwick
Stanwick Elrudge
Togatch Moneck (P.I. 30647)
Violet
Victoria
Wilkinson

The peaches and nectarines listed are varieties of the species *Amygdalus Persica* and *A. Persica* var. *nectarina*. The only other peach species tested were *A. Davidiana* (Chinese wild peach) and a hybrid between Elberta peach and the wild Chinese species, *A. mira*. Seeds of this hybrid were furnished by W. F. Wight of the U. S. Department of Agriculture Experiment Station at Palo Alto. They did not offer promising resistance, and approximately one third were infected with crown gall, caused by *Bacterium tumefaciens*. In previous tests, this species had proved highly susceptible to both crown gall and oak-root-fungus disease. Since a few seedlings of *A. Davidiana* were not attacked by nematodes in the nursery and several were not severely attacked in the test orchard, resistant ones might perhaps be developed. This species is, however, so susceptible to crown-gall disease that it cannot be recommended. Among more than 100 trees in the test orchard at Delhi (planted in 1930 and

top-worked to Paloro in 1934), only a few have survived the attack of crown gall and nematodes; but these have performed normally in growth and fruitfulness.

Besides Shalil, Bokhara, and Yunnan, the only other varieties that showed promising resistance were Quetta nectarine, Traveller nectarine, P.I. 61302 (a hybrid between Quetta nectarine and Bolivian Cling peach), and P.I. 41395 ("dwarf peach"). Lukens Honey and Early Wheeler peaches had a small proportion of resistant seedlings.

Though seedlings of Quetta nectarine show considerable promise, the seeds germinate so poorly that this variety cannot well be used. Traveller nectarine likewise gave a very low percentage of germination the two years it was tried.

In Georgia, Hutchins[5] reported seedlings of P.I. 61302 to be completely immune to nematode attack. In the California tests, however, a greater proportion were affected than of Shalil, Bokhara, and Yunnan. There was, also, a greater tendency to segregation into resistant seedlings and completely nonresistant ones; not only were the latter more heavily infested than was the case, for instance, with Shalil, Bokhara, and Yunnan, but a considerable numbere were retarded in growth. Not many seedlings of P.I. 61302 have been planted in orchards, but those that are growing appear to make unusually fine trees when budded to either peach or almond. Apparently, if seedlings of this variety are to be used in nematode-infested soil, they should be grown in a nursery on infested soil so that the nonresistant ones might be culled.

Experiments with an ornamental variety from China, P.I. 41395 ("dwarf peach"), are not sufficiently advanced to determine its usefulness as a rootstock, though it seemed to be as resistant as any tested. Being very dwarfish, it might not produce trees of normal size. Nine per cent of the seedlings, however, were apparently hybrids that were, in the nursery, as large as Shalil and other seedlings nearby and had especially good, widely spreading root systems. At two years of age, in the orchard, they were larger than nearby Shalil seedlings planted at the same time.

FIELD TESTS WITH RESISTANT PEACH STOCKS

To try out the resistant rootstocks on a practical scale, the authors undertook in 1933 to renew a mature peach orchard that was rapidly declining because of nematodes and the little-leaf disorder. This 20-acre plot was located near Delhi in a sandy soil; and many trees were dying, especially in the more sandy spots. Examination showed severe root injury by nematodes. The owner, therefore, had not had success in replanting with peaches on the commonly used rootstocks. Each year, as the old trees have become weakened and unprofitable, he has replaced them with resistant seedlings; and these he has top-worked to the desired varieties—Phillips, Gaume, Paloro, Peak, and Halford. When necessary, he has also treated both old and young trees with zinc to prevent little-leaf. Over this period, about half the trees have thus been replaced. A majority have now been in full bearing for four to five years; and the orchard, as a whole, has returned to profitable production.

To give these rootstocks a still more extensive test, under varying conditions, forty-eight smaller plots containing over 4,500 trees were set out in nine fruit

[5] Hutchins, L. M. Nematode-resistant peach rootstocks of superior vigor. American Society for Horticultural Science, Proceedings 34:330–38. 1937.

districts of California separated from north to south by as much as 300 miles. These were mostly in small areas of high nematode population, where the growers could not bring trees to maturity on the peach roots commonly used by nurserymen. This widespread test was deemed necessary because, both in the experiments reported here and in those conducted in other states, nematodes have behaved differently under varying soil and climatic conditions. Apparently certain "races" of the root-knot nematode prefer one species of root above all others, so that the presence of the roots of other tree and plant species may either increase or decrease the severity of infestation on the fruit-tree roots.

An example of the latter phenomenon was a chance peach-almond hybrid that appeared in a row of severely infested almond seedlings: though its roots were intermingled with others, not a single knot was evident in the whole root system. When, however, it was transplanted to a new position several hundred feet away, its new roots became covered with knots.

Another example is that of the seedlings from two selections of a flowering (ornamental) peach. In 1940 the seedlings of these selections in a test nursery at Atwater were practically free from nematode attack in a row adjacent to infested Shalil seedlings. Yet the following year, when tried in a test plot near Delhi, they were not more resistant than Shalil. Not a single seedling of either of these or of Shalil escaped infestation, and most of them were heavily attacked.

At first the aim was to determine in the nursery or in orchard plots what proportion of the seedlings of the nematode-resistant peach varieties were actually immune; at least, the degree of their resistance. After some years of work, however, it was found that the matter could not well be decided in this way—there are too many factors influencing the behavior of nematodes.

Other stocks besides Shalil, Yunnan, and Bokhara were included in the test plantings mentioned above; and almond as well as peach and nectarine was worked upon them by the owners of the orchards in which the plots were located. Figures 2 and 3 show the average growth obtained in these plantings. The test trees in the larger orchard mentioned above and in these numerous smaller plots have been closely watched, and most of them examined yearly for nematodes and for retarded growth in the individuals heavily infested. Table 1 gives the number of the Shalil, Bokhara, and Yunnan seedlings in these tests, with the percentage infested; also the percentage that was heavily infested.

Some of the plots were not included in this summary because, after planting, it was determined that there were not enough nematodes in the soil to make a fair test. Along one or more edges of other plots, trees were excluded because examination of the adjacent older, nonresistant roots indicated that there were not many nematodes present.

Of the heavily infested seedlings, only a few have been retarded by the nematodes. This response, however, has been difficult to evaluate because the heavily infested ones are, almost always, in sandy infertile spots, where non-infested as well as infested trees grow less rapidly than the nearby trees in better soil.

As the table shows, the three varieties do not differ greatly as to the percent-

age infested nor the percentage heavily infested. This finding, however, does not agree with the results in the test nurseries. Seeds of all three have been planted in the nursery each winter throughout eleven years. Although the results have been rendered variable by the "spotty" distribution of nematodes in the soil, the percentage of infested Shalil seedlings has been much less than that of the other two—except in the one year when all had some knots. The nursery that year was on a soil with an apparently higher concentration of nematodes (more uniformly distributed) than in any plot used earlier. In certain years of the test the concentration was sufficient for severe infestation of Lovell and other highly susceptible seedlings, whereas those of Shalil, Yunnan, and Bokhara remained entirely free. Of course unknown factors such as

TABLE 1

PERCENTAGE INFESTATION OF NEMATODE-RESISTANT PEACH SEEDLINGS IN ORCHARD TEST PLOTS

Seedlings	Total number test trees	Degree of infestation				Per cent infested	Per cent heavily infested
		Number free	Number light	Number medium	Number heavy		
Shalil (P.I. 63850)	326	262	6	31	27	19.63	8.25
Yunnan (P.I. 55885, 55886, and 55888)	461	387	22	25	27	17.61	5.85
Bokhara	701	551	26	81	43	21.39	6.13

soil temperature and the presence of different physiological strains of this nematode may have occasioned this difference. Perhaps, also, the nematodes were drawn away by more acceptable roots in the nursery.

To date no characteristic in any of these three stocks, when used in orchard planting, has appeared to favor one over the others. Several California nurserymen, however, chose the Shalil for seed production and during the past five or six years have sold to the trade over one million peach, nectarine, and almond trees on this root for planting in nematode-infested soils. They have sold relatively few on Bokhara and Yunnan roots. Fortunately the higher price charged for these stocks has limited their trial by growers almost exclusively to nematode-infested sandy soils. Until orchards have been grown on them for another decade, to prove that no unforeseen weakness will appear after a longer period or on various soil types, it is advisable (as a matter of precaution) that their use be restricted to sandy soils either infested with nematodes or liable to become so. There is some evidence that certain peach varieties on Shalil, on soils not infested with nematodes, may grow more slowly than they do on Lovell seedling roots.

In the nursery, Shalil, Bokhara, and Yunnan roots seem affected by crown gall to about the same extent as the Lovell. In some sections of Stanislaus County where young trees seem particularly susceptible to crown rot in wet-soil situations, or where a high covercrop kept the soil and the tree trunks moist during prolonged rainy spells in the late winter and spring, trees on Shalil appear more susceptible to crown rot than those on Lovell. Some confirmatory evidence has also appeared in commercial nurseries. In some pre-

liminary tests in a clay loam, however, the soil was kept saturated for 90 days about the crown of Shalil seedlings during the winter and early spring without damage to them. No comparison has been made, in this regard, with Yunnan and Bokhara except that in one small, wet spot in an orchard an equal number of Bokhara- and Lovell-rooted trees were affected; and except that in

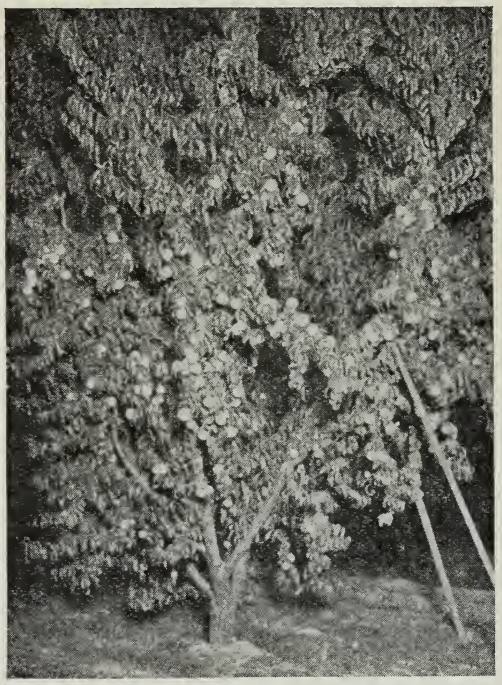

Fig. 3.—Gaume Cling showing excellent growth and productivity on Shalil peach seedling roots. Planted in the orchard in January, 1934. June-budded to Gaume in May, 1934. Photographed August 9, 1939. Tree props 9 feet long. Trunk diameter 7.2 inches. Height 19 feet. Estimated crop 400 pounds. (Courtesy of the American Society for Horticultural Science.)

another orchard Bokhara-, Yunnan-, and Shalil-rooted trees were killed, but no comparable Lovell roots were near by for comparison.

Seedlings of Shalil, Bokhara, and Yunnan grew more vigorously than those of other varieties and of the nonresistant Lovell—the one most commonly employed by nurserymen where the nematode is not concerned. This vigorous growth is especially useful in replanting old orchards where nursery-budded stock will not readily grow. Figure 3 shows Gaume Cling on Shalil, and figure 4 a two-year-old Shalil seedling 10 feet high among mature but decadent peach trees. Peach varieties budded in the nursery on resistant seedlings and transplanted to an old orchard have, however, often failed to grow well. Apparently the most successful way to renew an old orchard weakened by nematodes is to replant with resistant seedlings and to bud or graft them over to

the desired variety when they are two or three years old and have already made an extensive root system. Only under unusually good growing conditions should they be top-worked before they are two years old. Since the worst nematode infestation is in sandy, infertile spots, especial attention should be given to irrigation and to nitrate fertilization.

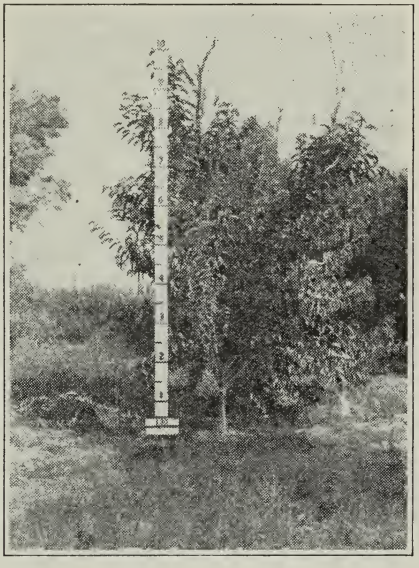

Fig. 4.—Seedling of Shalil planted among old trees weakened by nematodes and little-leaf disease. Diameter when planted (March, 1933) 3/16 inch; diameter when photographed (August, 1934) 2⅜ inches. Dead eucalyptus trees appear in the background.

TOP-WORKING NEMATODE-RESISTANT PEACH SEEDLINGS

Good success in top-working by budding in July and August has been secured with seedlings planted the previous spring and on up to three years of age. Buds can be inserted in two-year-old branches almost as successfully as in new shoots. As a rule, two or three buds are placed in each branch to make certain that at least one will succeed. Any branch on which the buds failed to "take" can be grafted the following February. The budded and grafted trees should be thoroughly sprayed to destroy peach-twig borers, for even one or two of these pests per tree may kill the developing shoots from the buds or grafts. Cutting back to the variety bud should be done in two steps rather than in one operation. The first cut should be made in late winter, 8 or 10 inches beyond the variety bud. In the spring, the tips of all the seedling shoots (both below and above the variety shoot) should be broken off after they have grown out 4 or 5 inches; and these should not be wholly removed till after the variety shoot is a foot or more in length. Then it is best not to remove them all—especially on the south and west sides. At this time the stub above the variety shoot

can be cut cut back closely. The treatment described above avoids the setback or so-called "shock" from too heavy pruning and prevents sunburning on the sunny side. If, furthermore, unnoticed twig borers are present, or control methods happen to fail, there will be many tender shoots for this pest to attack rather than just the variety shoot. Often, in windy situations, the orchardist must allow the seedling shoots more freedom of growth and cut off the tips of the variety shoots when they are 18 to 24 inches high, to prevent their becoming top-heavy before the basal portions have gained sufficient strength. At pruning time the first winter, the tops should not be cut back too heavily, because this pruning constitutes a second year of heavy heading and a consequent setback in growth. To defer top-working longer than the third year is not advisable: large cuts in peach branches are liable to become infected with wood-rotting organisms before they can be completely callused over.

GERMINATION OF SEEDS OF THE NEMATODE-RESISTANT PEACH VARIETIES

The pits of Shalil, Bokhara, and Yunnan peaches require three to four months in damp soil at winter temperatures to break the rest period before the seeds will germinate. As a rule, pits thus "stratified" about the middle of October in a shady location will break open and their embryos begin growth by planting time—that is, by the middle of January or the first part of February. Pits not broken open by then can be germinated if they are carefully cracked with a hammer and the uninjured seeds planted. The poor germination of seeds of Quetta and Traveller nectarines has already been mentioned. Good germination was usually had with P.I. 41395 ("dwarf peach") and with the Quetta × Bolivian Cling hybrid.

ORIGIN OF THE NEMATODE-RESISTANT PEACHES AND NECTARINES

Shalil.—The Shalil originated from seeds imported in 1913 by the United States Department of Agriculture from India, where a variety is known by this name. One seedling grown from these seeds was given the P.I. number 36485 (later changed to 63850 for convenience in distribution) and named Shalil. It is a freestone. Two other selections from the same lot of seeds were given no names, but merely the numbers 63851 (a freestone) and 63852 (a clingstone). All three are yellow-fleshed and are not of very high quality as fruits. The dried product from fruits of Shalil allowed to become very ripe on the tree, though lower in culinary quality than dried Lovell peaches, have been sold at an equivalent price.

Seedlings of all three selections have been tested both in nurseries and in orchards. Though they seem to possess similar qualities in regard to nematode resistance, growth, and other characteristics, Shalil has received most attention. Several seedlings of each have been fruited; and the seedlings of these have been tested for resistance, but with inconclusive results. Apparently none of these open-pollinated, third-generation trees yield seedlings more resistant than the second generation; and in several cases there is perhaps a decrease in resistance. (The seedlings grown from the originally imported seeds are here

considered to be the first generation; that is, that Shalil and P.I. 63851 and P.I. 63852 are first-generation seedlings.)

The Shalil (63850) seeds used in these experiments were produced on trees at Davis and surrounded by many nematode-susceptible varieties of peaches that perhaps could have pollinated the Shalil flowers. It was at once thought that possibly the resulting hybrids might be less resistant than if they were self-pollinated, and that seeds grown on trees far removed from susceptible varieties might have greater resistance. Attemps at self-pollinating them by hand, after emasculation, failed to produce a single fruit in three seasons at Davis. Shalil (as the pollen parent) has, however, been successfully crossed with Bokhara, Yunnan, Lovell, and Muir peaches. Judging from tests, the seedlings from these seeds have about the same degree of resistance as the Shalil parent. In the years in which these hybrid seedlings were tested, however, the nematodes, though sufficiently numerous to injure the Lovell seedlings severely, were not in high enough concentration to give conclusive comparative results. Recent work in the United States Department of Agriculture by Long and Whitehouse[6] and by Weinberger and his co-workers[7] also shows that nematode resistance is a dominant character in the resistant varieties and that crossing with pollen from nonresistant peaches should not decrease their resistance; also that pollen from resistant varieties may carry the resistant character to the seedlings of susceptible varieties.

The inventory[8] of seeds and plants imported by the United States Department of Agriculture states, in regard to No. 36485 (63850), that the Shalil peach was discovered growing at an elevation of about 5,600 feet in Kurram Valley, Northwest Frontier Province of India. "In winter even Lower Kurram is very cold and a bitter wind prevails, while in the summer it is hot and dry. Upper Kurram is never unpleasantly hot, even in summer, while in winter snow covers the ground for weeks." Being thus a cold-climate tree, in California it sometimes holds its leaves almost throughout the winter months, and its rest period is often not sufficiently broken by springtime. Since, however, the roots of trees are not subject to rest requirements, this characteristic will probably not affect its usefulness as a rootstock.

Bokhara.—According to Hedrick,[9] this peach was introduced into America by J. L. Budd about 1890 from seeds received from Bokhara (Bukhara) in Russian Central Asia. Several selections from this lot of seeds have been propagated under the name Bokhara. Possibly seedlings from seeds of these several "Bokhara" strains might exhibit totally different reactions to nematode attack. The Bokhara used in these experiments is a white-fleshed freestone. Several growers who were furnished seedlings of this variety have been particularly impressed by its general behavior. Hand-pollinated hybrids be-

[6] Long, J. C., and W. E. Whitehouse. Variations in root knot nematode infection of various lines of peach progenies at Chico, California. American Society for Horticultural Science, Proceedings 43:119–23. 1943.

[7] Weinberger, J. H., P. Marth, and D. H. Scott. Inheritance study of root knot nematode resistance in certain peach varieties. American Society for Horticultural Science, Proceedings 42:321–25. 1943.

[8] U. S. Dept. Agr. Bureau of Plant Industry. Inventory of seeds and plants imported. No. 37. 1916.

[9] Hedrick, U. P. The peaches of New York. New York Agr. Exp. Sta. 24th Annual Report. Vol. 2, part 2, p. 1–541. 1917.

tween it and Shalil and Yunnan, respectively, seem to be approximately as resistant to nematodes as the seedlings from open-pollinated Bokhara seeds. Seedlings from self-pollinated flowers of Bokhara apparently showed no more resistance than did seedlings from open-pollinated flowers. Nor did third-generation seedlings (open-pollinated) of Bokhara differ in resistance from the second-generation ones.

Yunnan.—The Yunnan peaches are a group of three selected seedlings from trees found growing wild in the mountains in Yunnan province, China. Seeds were imported by the United States Department of Agriculture in[10] 1922; and three of the seedlings were selected and numbered respectively 55885, 55886, and 55888. In the wild, at an elevation of 5,000 to 5,500 feet, the original trees from which the seeds were secured were white-fleshed clingstones and attained a height of 40 to 50 feet. Yunnan 55885 and 55888 are clingstones, whereas 55886 is a freestone; all have white flesh. At Davis the freestone variety is a shy bearer. For seed purposes, nurserymen have generally preferred to take propagating wood from 55885, apparently the most productive of all. No. 55888, however, produces fairly well. In the tests separate records of nematode resistance were kept of each; but since the results were similar, the three are reported together as one in the table.

As with Shalil and Bokhara, the third-generation seedlings have not differed perceptibly in resistance from the second generation, and crosses with Muir peach apparently retain the resistance of the parent Yunnan.

Quetta Nectarine (P.I. 34684).—This variety was selected from seedlings developed from nectarine seeds imported in 1906 from the city of Quetta in northwestern India, by the United States Department of Agriculture. (Shalil, Bokhara, and Quetta all came from central Asia; the Yunnan group from southeastern Asia.)

P.I. 61302.—This peach was produced by J. E. Morrow at the U. S. Plant Introduction Gardens at Chico, California, by crossing Bolivian Cling (P.I. 36126) with the Quetta nectarine. Bolivian Cling is a white-fleshed peach selected from seedlings raised from seed collected by Edward M. Ehrhorn from trees planted in Bolivia by the Franciscan padres. As seedlings of the Bolivian Cling are not resistant, the Quetta nectarine seems to have furnished the resistant factor in this hybrid.

Traveller Nectarine.—This is a chance seedling selected by Tribble Brothers, who for years conducted a nursery at Elk Grove, California.

[10] U. S. Dept. Agr. Bureau of Plant Industry. Inventory of seeds and plants imported. No. 73. 1922.

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